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THE TYPES OF INJURIES TO BE EXPECTED IN AIR RAIDS.

Air raid casualties in the present war have been relatively small in number, but very varied in type. The small number has been a matter for surprise, but the variation in type could have been readily predicted, had one remembered that bombs not only destroy life directly, but also occasion numerous indirect hazards. It still remains true, of course, that certain types of air raid injury predominate, and it is the aim of this article to direct attention to these. This will be done by considering three main themes: the common causes of injury in air raids, the factors influencing the number of casualties, and the clinical classification of the common injuries.

Causes of Injury in Air Raids.

The offensive weapons of air warfare are: (*a*) high explosive bombs and parachute mines; (*b*) incendiary bombs; (*c*) machine gun fire; (*d*) poison gas.

In addition, shell fragments from anti-aircraft guns are likely to injure civilians. It is stated that some 25% of the total casualties caused in Great Britain by the air raids of 1917-1918 were due to this factor, but, with modern methods of shelter, it is less important today.

The high explosive missiles used by the Germans in their air raids on England in this war have been one hundred, five hundred, one thousand and up to four thousand pound aerial bombs, and, in addition, one thousand pound and one ton land mines.[3]

A hundred pound bomb will usually destroy one or two rooms of an average four or six roomed brick house. Unless it falls right in the middle, the remainder of the house is relatively unaffected. If the bomb falls in a street, it penetrates the surface and lifts up a heap of earth, twenty to thirty feet in diameter, and three to five feet in depth. This may be sufficiently deep to interrupt all the five services—water, gas, electricity, sewerage and telephone. In London, trained demolition and repair squads work with incredible speed, however, and can usually have these repaired in ten to fifteen hours. There is often no serious interference with traffic. It is said that taxi-drivers are now accustomed to pull up before the back wheels of the car have gone into the crater, and, after reversing quietly out of it, imperturbably seek an alternate route.

A five hundred pound bomb landing in a street makes a hole eight to ten feet deep, and seventy to one hundred feet in diameter, and breaks windows up to two hundred and fifty yards away.

A one thousand pound or two thousand pound land mine may more or less demolish a city block, if it strikes favourably, and it often topples buildings over at several hundred yards.

No details are available concerning the "super-bomb" that the British are now using, but it is evidently "super" in the sense of having greater explosive charge. It is reported to have a weight of two tons. The havoc wrought by such a bomb in closely built areas would be colossal.

The heavier high explosive bomb (five hundred pounds or more) is used against built-up areas, but the civilian population, of course, suffers incidentally, and the name of "general purpose" bomb is well merited. As mentioned before, these bombs penetrate ten to twenty feet into the earth. This dampens the direct lateral spread of the concussion; but earth waves are set up as a result, and there is even actual displacement, plastic and elastic, of the surrounding earth, as it is pushed aside by the explosion.

There is an enormous dispersion of earth and bomb fragments, upwards and slightly outwards, in such a way that the flying particles trace out a cone with the bomb at the apex. Objects within a few feet of the crater may, at times, be undamaged.

The fragments from these heavy bombs are often large. If they strike a man's limb, they may tear it off; if they strike his head, chest or abdomen, they usually kill him.

The second type of casualty produced by heavy bombs results from the collapse of buildings. People injured in this way rarely have obvious wounds, except for occasional head wounds, but many of them have fractures, internal hæmorrhage, crushing of the chest or ruptured viscera, and they are often so completely covered with dust and dirt as to be unrecognizable until they have been washed. One special and important type of injury caused by falling masonry results when a man is pinned down by débris for some time.

The collapse of buildings and the resulting havoc cause casualties in other ways. Some persons are buried and suffocate, some are trapped in confined spaces, some are poisoned by carbon monoxide, some are drowned in basements, some are burnt, some are electrocuted, many suffer psychologically, and some are deprived of food and shelter and exposed to increased risks of infectious disease.

Blast from large bombs may injure a person in still other ways—directly ("blast concussion"), or by producing a fall, or by setting in motion secondary missiles such as glass, stones and débris. Of the injuries caused by secondary missiles, many have been due to glass.[3]

The other type of high explosive bomb is the fragmentation bomb, a smaller bomb, about four to thirty pounds in weight, used to attack personnel. These bombs are covered by a light material which splinters into thousands of pieces when the explosion occurs. The so-called "liquid air bomb" is of this type. The crater produced is shallow, so that the dispersion of splinters occurs in a horizontal direction as well as in a vertical. The violence of the explosion is very great and may break windows half a mile away. Small splinters are therefore driven outwards with great velocity and produce multiple wounds. At as close a range as twenty-five feet or less many of the fragments may be as small as a pin-head, but their velocity is considerably greater than that of a rifle bullet.

The "anti-personnel" bomb used by the Japanese is of this type. Within a radius of twenty to forty yards this bomb is very destructive, and sweeps even grass off the ground. Any person trying to shelter himself by lying on the earth within this distance from the bomb is often cut to pieces and is usually rendered unrecognizable.

The incendiary bomb may be small, weighing only two to three pounds, but larger bombs containing phosphorus or oil have also been used. The effectiveness of these bombs is conditioned, of course, by the amount of wood or other inflammable material present in the area under bombbardment.

The machine gun fires a smooth bullet of high velocity which may kill at two miles. When it strikes a human being it commonly produces a small hole of entry, but this does not hold if the casing is damaged, or if rotation has been caused by the bullet striking some obstruction in its flight. Machine gun fire may be directed against people in streets, but as this necessitates low-flying machines, it is uncommon when the defence is reasonably good.

Poison gas has not been used in the present war so far. It may be sprayed from aeroplanes or dropped in special bombs with a low bursting charge.

Types of Injury.

The above account gives a brief description of the causes of air raid injury in terms of the offensive weapon used. The injurious agents can be described from a more strictly medical point of view, however, by considering them as the cause of the following injuries: (*a*) penetrating wounds; (*b*) crush injuries; (*c*) blast injuries; (*d*) burns and scalds; (*e*) gas poisoning; (*f*) psychological trauma.

Penetrating Wounds.

An important characteristic of many penetrating air raid wounds is that they show tissue destruction out of all proportion to the size of the splinter which causes the wound. This is because the destructive power of a missile is largely dependent on its kinetic energy, which varies directly as the mass and the square of the velocity. The velocity of high explosive bomb splinters is extraordinarily high (three thousand feet or more per second) and this more than compensates for their small mass.

When the splinter penetrates the body it imparts momentum to all the tissues with which it comes in contact, and the effect has been compared to that of a secondary internal explosion. The more elastic the tissue, the less likely is it that damage will be widespread; but, whenever the elastic limit is exceeded, rupture of the tissue occurs. Certain inelastic tissues such as bone therefore fare very badly, and comminuted fractures may be found at appreciable distances to one side of the track of the missile. The liver is also relatively inelastic, and a missile passing through it may split it to pieces. Muscle is more elastic and is not so easily damaged, but a high velocity missile may nevertheless leave a large area of devitalized hæmorrhagic muscular tissue extending for several cubic inches around the actual track.

Naturally, empty hollow viscera, being mobile, are much less likely to be injured in this indirect way than they would be if full. Blood vessels and nerves are usually elastic enough to stand the strain without anatomical injury, though the nerves may show functional impairment. Skin, of course is very elastic, and this has the important practical result that a small skin wound may overlie a large area of devitalized tissue.

These effects of high velocity bomb splinters have often been incorrectly explained in terms of the jagged nature and rotatory movement of the fragments; but it is not necessary to have an irregular missile in order to get a widespread and often bizarre type of destruction around the wound track. All missiles travelling at high velocity produce very violent effects in soft media, for example, clay or flesh. This effect is not seriously altered by any peculiarities of shape or rotation, as is indicated by the neat holes which irregular missiles make in hard wood. This probably explains why in the early stages of the last war the combatants each suspected the other of using dum-dum bullets.

From time to time it is suggested that bomb splinter wounds are sterilized by the heat of the splinter, especially as the tissues may sometimes be charred. The temperature of the particles at the beginning of their flight may be anything up to 300° C.; but non-sterile clothes and débris are often carried into the wound without having been heated. Experience, too, shows that these wounds are very prone to become infected.

It has already been emphasized that bomb splinters give a special type of penetrating wound, owing to the high velocity of the fragments. Even rifle and machine gun bullets, whose striking velocity is generally less than that of bomb splinters, cause their destruction at least partly by the momentum they transfer to tissues along their path. The damage caused by these more slowly moving missiles, however, is mainly due to destruction in the actual path. The projectile moves relatively slowly through the body, destroying and displacing tissue with which it comes in contact. Secondary missiles are mainly of this slow-moving type, and it is obvious that their shape has an important influence on the variety of wound produced. Mention should be made of the frightful wounds sometimes inflicted by flying glass. Abdominal casualties have been partly eviscerated, festoons of damaged intestine have even been herniated in front or behind, while there have been tragic facial disfigurements in women, with damage to, or loss of, the eyes.

The course of a missile after contact with the body is unpredictable. A well-known surgeon once stated that he was prepared to believe anyone's story about the behaviour of any missile entering a human frame, and he could add a few himself. In particular, mention should be made of the frequency with which missiles entering the buttock pass on into the abdominal cavity.

Crush Injuries.

A crush injury is characterized by acute renal failure supervening in people who have been pinned down by falling masonry or have been buried or subjected to pressure for a varying period. It is more correctly termed the "compression syndrome" because the effect is not a straight-out result of crushing; the time during which the pressure is maintained is important, and this time factor is recognized by the use of the word "compression".

People who show this syndrome may have no obvious local injury. When a local injury does exist, it takes the form of local swelling and œdema, followed by bullous eruption; in the case of a limb, anæsthesia may be produced by the pressure. A few hours later, in spite of obvious vaso-constriction, the blood pressure falls and hæmo-concentration occurs. Later still the urinary output diminishes and albumin and dark brown clots are found in the urine. The patient becomes alternately alert and drowsy; his blood pressure often rises. General œdema, vomiting and thirst supervene, the blood urea becomes increasingly high, and death frequently occurs about the seventh day. The three characteristic clinical features, therefore, are the comparatively good condition of the patient on admission to hospital, then circulatory failure which responds to transfusion, and finally progressive renal failure.

It has been noticed in England that falling buildings cause more non-fatal than fatal injuries.[1] The conclusion has been drawn that, since a large number of these injuries are not severe enough to cause death, a substantial percentage of them may be avoided by an efficient indoor shelter able to bear the weight of falling material.

Blast Injuries.

When a bomb bursts, a wave of increased pressure, followed by a smaller wave of decreased pressure, moves outwards from the region of the bomb. The wave of compression can cause injury, especially to the lungs, but also to other organs, and to the ear drums.

"Lung blast" is due to the compression wave striking the chest. The chest wall, lung and contained air act as a solid body which is rapidly compressed by the wave. The alveolar capillaries, being the weakest structures, rupture and alveolar and interstitial hæmorrhages are

produced. There is intense dyspnœa and some hæmoptysis, with no evidence of an external wound. There is abundant experimental evidence to show that blast does not act on the lungs by forcing air down the trachea.[4]

"Blast" lesions of the abdominal organs take the form of hæmorrhages and occasional rupture of a solid viscus. The rupture of the ear drums is important, since it provides good evidence of exposure to blast, and helps to clear up what is sometimes a difficult differential diagnosis.

If death occurs, it may be immediate as a result of primary shock from extensive visceral lesions; it may also be delayed, in which case it is due to pulmonary œdema or continued hæmorrhage from an abdominal lesion. Death from pulmonary œdema is by far the most common of these three types.

There are two factors which make blast injuries relatively rare among patients admitted to hospital. The first is that humans are comparatively resistant to such injuries. Most windows will break at a pressure of five to ten pounds to the square inch, but a pressure of one hundred pounds is required to injure the human lung. A man is quite safe from blast thirty feet away from a one hundred pound bomb.

The second point is that the wave of pressure decreases quickly in intensity as it moves outwards. This means that the distance between the spot where one is killed by blast and the spot where one is uninjured is relatively small. A seventy pound charge causes a pressure of one hundred and ten pounds per square inch at fourteen feet, and fifteen pounds at thirty feet.[9] It has therefore been the experience in England that few of the casualties admitted to hospital are suffering from blast. One hospital reports three hundred consecutive admissions following air raids, without a single unequivocal case of blast.[33]

A special type of blast injury occurs in those cases in which the blast waves are transmitted through water. A typical instance is the case of a man swimming in water when a depth charge explodes near by. The main feature in these cases is subperitoneal hæmatomata. The abdomen is affected more than the chest because it is more exposed to the concussion wave. Lung blast, of course, coexists, and is sometimes severe, but is not the characteristic feature. Testicular compression has also been reported, and often produces severe pain.

Burns and Scalds.

In an air raid, fires are caused by high explosive bombs as well as by incendiaries. Escaping gas often catches alight. Whenever shipping is heavily bombed, fires are almost inevitable and are sometimes complicated by the escape of oil on to the water. This oil burns fiercely.

Burns may be relatively common amongst the rescue squads. They present the usual serious problems. One special wartime complication is that a man who has been burnt by the "flash" from a bomb is likely to be suffering from blast. This latter may easily be overlooked in the circumstances, and the patient be given an inhalation anæsthetic, with greatly added risk to life. Phosphorus burns too require special treatment.

Gas Poisoning.

Poisoning from carbon monoxide results from leakage from damaged gas mains and from the explosion of bombs in a confined space. Refrigerator plants are so common that they are often damaged in air raids. Forty-seven persons were poisoned in England during one incident when a refrigerator plant was hit and ammonia leaked into an air raid shelter.

Gas poisoning may become a major problem if the combatants resort to chemical warfare.

Psychological Trauma.

The small number of psychiatric casualties that have resulted from air raids in England has been a matter for surprise. The average previously healthy citizen has proved remarkably adjustable. For example, an analysis of three hundred patients admitted to a mental hospital in a district that had been bombed, showed that in only four could the air raids be regarded as having a major influence, while in a further six it was but a contributory factor in causing the mental disorder.[1] Similarly the incidence of convulsions in epileptic patients has shown no increase.

On the other hand, temporary emotional shock is very common after a raid, except in the case of children. About 20% of seven hundred persons seen at a first aid post were suffering from the effects of fright and anxiety, ranging from acute emotional disturbance to hysterical paraplegia and stupor.[2] Most of these people could be persuaded to admit and accept their fear, and practically all returned to normal.

A very severe bombing experience is needed to produce a psychoneurosis in normal people. The breakdown may occur after a lapse of several weeks and usually takes the form of hysteria associated with amnesia.

Patients with established hysteria are likely to have exacerbations during raids, but the existence of an anxiety state or obsessional state before the raid gives, according to one writer, "a greater feeling of security than sixty feet of concrete". One of his patients had said to him: "Oh, I'm not worried about the bombs—it's this queer tickly feeling in the back of my head." A woman with obsessional fears of murder and suicide and knives said: "I'm afraid I can't get very concerned about bombs."

A few cases of manic-depressive psychosis have been reported, but chiefly in people of a psychopathic type.

The greatest sufferers from psychological trauma are the elderly men and women who have been bombed out of their homes. Their power to adjust themselves is poor, and, if they are sent to the unfamiliar surroundings of a hospital, they may become disorientated and depressed, and may die rapidly.

Frequency of Different Types of Injury.

The chief causes of injury in air raids have now been enumerated, and it remains to consider their relative frequency. Figures obtained as to the types of injury during one raid on Bristol were:[7] Killed: 76% by splinters, 8% by blast, 16% by crushing and falling masonry. Injured: 38% by splinters, 9% by blast, 52% by crushing and falling masonry, 1% unclassified.

It is obvious that these figures may vary widely from place to place. In another raid in which falling masonry was not a factor, but in which a fire was caused aboard a ship in a harbour and machine gun "strafing" was used, the non-fatal injuries were produced as follows: 46% by bomb fragments and bullet wounds, 23% by burns, 13% by burial under earth or débris, 11% by falls resulting from blast, 5% by shock, 1% by falls resulting from accident, 1% by blast.

The above figures reveal the variation referred to. They would be more informative if different writers used similar classifications. Until more uniformity in this regard is secured, a great number of wartime statistics on injuries will be robbed of much of their value.

Number of Casualties in an Air Raid.

The risk rate of a population exposed to injury by air raids cannot be calculated theoretically with any great accuracy. London expected thirty thousand to one hundred and fifty thousand casualties per raid. The published figures show that about one hundred were killed and one hundred and fifty injured per day during the one hundred days of intensive air attack toward the end of 1940.[3] The figures for other cities are different.[7] It seems that a city can accurately estimate its risk rate only by actual experience.

The probable reason for the gross over-estimate of the number of casualties likely to occur in London is interesting. The calculation was based partly on English experiences from September, 1917, to May, 1918, during which time fifty tons of bombs were dropped, causing casualties at the rate of seventy-five per ton by day and twenty-nine per ton by night. The very high rate of injury was almost certainly due to lack of defence, including shelters. This point is illustrated by some figures

for Barcelona and Tarragona during the Spanish War. Up to February 5, 1938, eighteen persons were killed per ton of bombs. At that date shelters became widely available, and the deaths per ton of bombs dropped to six in March and one in June.

Two facts of general validity about the risk of injury are that it is greater for men than for women,[7] in the proportion of five to four, and that, bomb for bomb, casualties admitted to hospital are more numerous and severe in daytime than at night.[8] This latter fact is partly due to the greater ease of collecting casualties during the day, so that seriously injured persons brought to hospital then might have died untended if they had received their injury at night. Another reason, however, is that the typical daytime incident is an explosion in a crowded street; whereas at night the streets are relatively deserted, and the common incident is the bombing of buildings. When buildings are bombed, people in the smaller buildings suffer badly, but the majority seek shelter in modern ferro-concrete structures and injuries come mainly from slow velocity secondary missiles.

Clinical Classification of the Common Air Raid Injuries.

The casualties can be divided into three main groups—those with minor injuries, those with severe injuries and those dead. In most instances the dead outnumber the severely injured. It was calculated in London that 40% of those sufficiently hurt to be termed casualties had been fatally injured.[9] Those receiving minor injuries are about half as many as those receiving major; so that 40% die, rather less than 40% have major injuries, and rather more than 20% have minor injuries.

Minor Injuries.

Minor injuries are dealt with mainly at the first aid post, and one first aid post in Bristol analysed two hundred and fifty consecutive cases as follows:[10] 50% eye injuries, including burns to the eye; 10% burns of hands and limbs; 10% head injuries; 25% wounds of limbs; 2% wounds of trunk; 3% shock.

Of these, 10% were sent on to the hospital, 5% at once and 5% the next day. The large number of burns was due to the fact that fire brigade headquarters were nearby, so that many fire fighters attended the post.

Major Injuries.

In a series of over four thousand injuries, the cases, classified on an anatomical basis where possible, are shown in the accompanying table.

Injury or Site of Injury.	Percentage of Total.	Percentage Mortality Rate.
Lower limb	19	5
Cranial	18	7
Upper limb	11	3
Maxillary and facial	6	3
Chest	5	8
Back	3	4
Eye	2	0
Spinal	1	10
Abdominal	1	17
Neck	0·5	4
Pelvic	0·5	50
Multiple	8	17
Abrasions and cuts	7	1
Burns	3	11
Shock	15	5

The fatality rate amongst all casualties admitted to hospital was 6%. This rose to 9% if one included those who were dead on arrival at hospital.

It will be noticed that wounds of the face and cranium are very common, making up one-quarter of the total casualties, and causing one-quarter of the total deaths in hospital.

Penetrating wounds of the head are readily missed unless careful examination is made. Rock Carling tells the story of a first aid doctor who complained that he had many insignificant wounds of the scalp to attend to. "Yes", said the surgeon who had received his patients; "you sent eleven to hospital in one night; four had foreign bodies in the brain, and the other seven had depressed fractures."

The relatively low figures for chest and abdominal injuries are obviously not due to the fact that the missiles selectively avoided these areas; but rather because large numbers of chest injuries, and even larger numbers of abdominal injuries, were quickly fatal. The relatively high incidence of eye injuries, considering the small anatomical area exposed, reminds one of the vulnerability of this important region, and gives some support to the view that those who must work on during air raids should be provided with a vizor. The number of cases of shock, though as high as 15% of the total, is misleadingly low, since many of the factors which produce shock are present in every serious injury.

There is general agreement between these figures for the present war and the less detailed statistics of over nine thousand cases supplied by Trueta from the Spanish War:[6] multiple major injuries, 33%; lower limb, including hip, 22%; upper limb, including shoulder, 15%; thorax, 12%; abdomen, 9%; head (skull and face), 8%.

Summary.

The above information concerning the types of injury that may be met with in air raids may be summarized as follows.

1. In general, the total casualties in air raids are smaller than has been expected.
2. The fatal cases amount to 40% of the total casualties.
3. Penetrating wounds inflicted by bomb splinters are characterized by much more destruction of tissue than is at first apparent.
4. Injuries inflicted by flying glass are relatively common and sometimes very serious.
5. Crush injuries from falling masonry *et cetera* are very common and have introduced special problems of their own.
6. "Blast" injuries to the lungs are not very common.
7. Burns and scalds depend for their incidence on the type of area or situation bombed; at times the incidence is high, but, in the main, not so high as would be expected.
8. Injuries to the head and neck make up approximately one-quarter of all serious injuries.
9. Eye injuries of various types are relatively common, and special arrangements have to be made to deal with them.
10. Psychiatric cases are not nearly so common as was expected.

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